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APPLE, QUINCE, & PEAR ROOTSTOCKS IN CALIFORNIA

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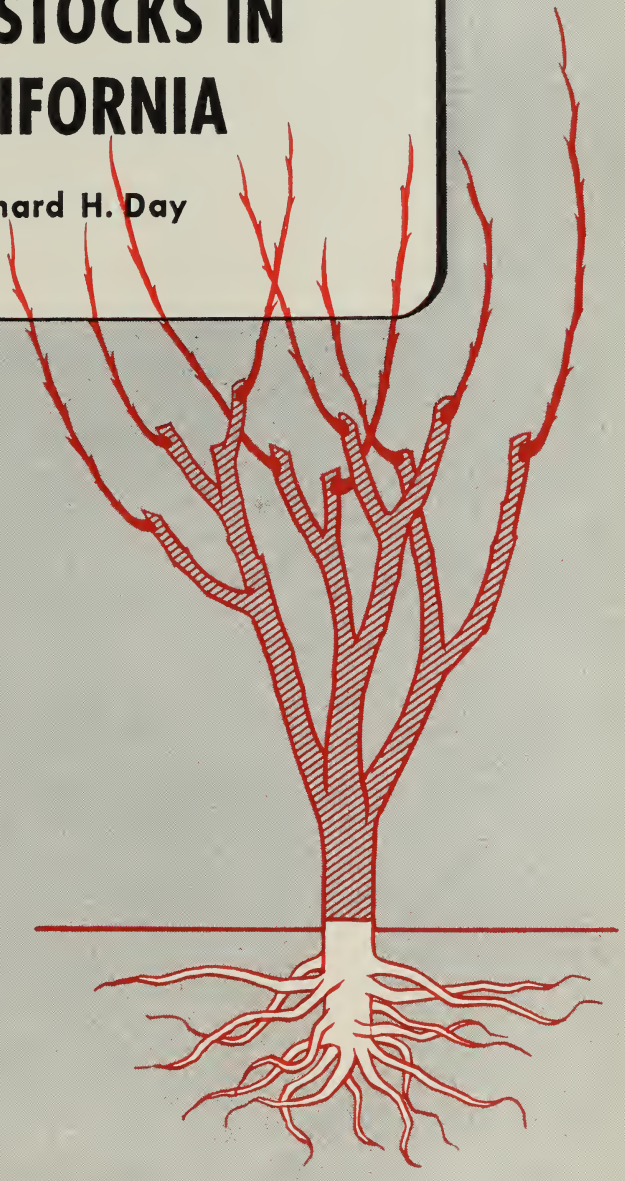

THE COLLEGE OF AGRICULTURE
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THIS BULLETIN has been prepared to inform the nurseryman and the fruit grower concerning rootstocks for apple, quince, and pear

The Bulletin lists varieties which produce good seedlings and those which do not. It points out that even favorable varieties differ in suitability as rootstocks. The insect pests and diseases which attack the rootstocks of each species are discussed in the report on the search for pest- and disease-resistant seedlings. The relation between rootstock and climate, soil, planting, irrigation, and pruning is also discussed. Observations and experiments with various roots and intermediate stocks are recorded for these fruits. Outstanding conclusions in each section are given:

APPLE is the only rootstock on which apple varieties have been grown commercially in California. The so-called French seedlings, obtained chiefly in Oregon and Washington, are the only ones now available; apparently they are as satisfactory as those formerly obtained in Europe. A well-tested, good rootstock resistant to woolly apple aphid is desirable, but no completely satisfactory one has yet been demonstrated.

QUINCE varieties are grown only on roots of their own species. The greatest use of rooted quince cuttings in California is for rootstocks for pear trees. For this purpose, the Angers type is used. Since quince root is tolerant of rather wet soil conditions, it is often used as stock for pear in low wet spots in pear orchards.

PEAR is grown in California on the so-called French pear roots, with or without blight-resistant Old Home as an intermediate stock. The French roots now used are mostly seedlings from Bartlett seeds. Quince roots with Hardy as an intermediate stock are also used. Apparently Old Home could be used, too, as a substitute for Hardy, as the intermediate stock. When planted with the graft union 10 or 12 inches below ground, it would produce Old Home roots above the quince, and thus furnish resistance below as well as in the trunk and scaffold branches.

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LEONARD H. DAY[2]

INTRODUCTION

This report summarizes observations on rootstocks for apple, quince, and pear during some thirty years at the University of California Agricultural Experiment Station at Davis, and in the various districts in California where these fruits are grown. The earlier experimental plantings were made by Dr. W. L. Howard and Dr. W. P. Tufts. Several other members of the Pomology staff have contributed observations or experiments, as noted in this report. More than thirty years ago, growers began trying new rootstocks for pears in an effort to avoid losses from fire blight and pear root aphid. Many of these plantings, observed from the beginning, have long been old enough to yield valuable information regarding both their merits and their faults. For some sixteen years, the author has been planting test plots of apple, quince, and pear rootstocks at Davis and in several counties in the state; and now, some of these experiments are of sufficient age to warrant publication of results.

ROOTSTOCKS USED FOR APPLE VARIETIES

In California, apple is the only root on which apple varieties have been grown commercially. Except for certain orchards planted during the past thirty-five years, practically all the old apple orchards today are growing on seedling apple roots imported from France, by nurserymen, either as seeds or as seedlings and commonly known as French, French crab, or French cider seedlings.

The apples used in France and Austria for cider purposes are mostly small-fruited forms of the common varieties, *Malus domestica* Borkh, which have run wild. The seedlings, if allowed to grow to maturity, seldom bear large fruits. The fruits, which are usually inedible, are astringent and lacking in pleasant aroma. Apparently, the imported French seedlings were mixtures derived from seeds of cider, common dessert, and cooking varieties from the cider presses of France and Austria. This difference in parentage might have been expected to result in a great variability in vigor and compatibility. Uniformity of trees in old orchards in California indicates, however, that the French seedlings made satisfactory rootstocks. Weak seedlings, of course, may have been largely weeded out in nursery operations.

Early settlers near Fort Ross, in Sonoma County, used seeds from the old orchard planted there about 1812 by the Russians (Wickson, 1926).[3] A variety known as Fort Ross, or Russian apple, was grown in Green Valley, in the same county, and seeds of this variety were also used. The sturdy character of some of the old orchards in Sonoma County is attributed by certain growers to that

[1] Received for publication December 2, 1946.

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[3] See "Literature Cited" for the name of author and title of the books and papers cited in the text.

root. Which apple was used is now impossible to determine, for there remains of the original planting at Fort Ross only Gravenstein and a small apple locally known as Russian Bellflower. Old apple trees planted there after the Russians departed in 1841 are common varieties. In 1937, E. O. Bremner, Agricultural Commissioner, located at Santa Rosa, reported to the author that seeds of the Romanite or Red Roman were favored by early nurserymen in Sonoma County. Since these names have been applied to several varieties, however, it is not certain that this is the true Romanite apple. According to Butterfield (1938), in 1850 William H. Nash and R. L. Kilburn brought from New York trees of Red Romanite and of other varieties, and planted them near the present site of Calistoga, Napa County. These plantings were perhaps the source of the Red Roman used by the early nurserymen of Sonoma County.

During the latter part of the nineteenth century, most of the trees in the Sonoma County district were planted on the imported French root. In recent years, however, the stock has come from Oregon and Washington.

In the Watsonville district, probably most of the first apple trees were on seedlings of apples from the Mission gardens; but the commercial orchards—the first of which were planted about 1860—apparently were propagated mostly on imported French stock. H. A. Hyde, nurseryman of Watsonville, in correspondence with the author in 1938, stated that perhaps for the period between 1900 and 1910 most of the rootstocks for the apples grown in that district—as well as in the rest of northern California—were about equally divided among three sources of supply: Europe; the Midwest; and Oregon, where the nurserymen were just beginning to produce seedlings. From 1910 to 1920 most of the rootstocks came from the Midwest and Oregon, and since 1920, practically all of the seedlings have been grown in the Pacific Northwest. Probably the Midwest seedlings were grown from seed imported from France.

Practically all of the apple trees offered by California nurserymen are on seedlings of American origin, mostly from Oregon and Washington. According to some nurserymen of the Pacific Northwest, growers of seedlings use mainly seeds of Delicious, Rome Beauty, Winesap, Yellow Newtown, Black Twig, Winter Banana, and Stayman Winesap. The first three are said to be preferable from the standpoint of uniformity and vigor in the nursery, and seedlings of Jonathan are reported inferior in vigor in the nursery to those listed above. They are likewise considered undesirable at the Iowa station (Drain, 1940). On the other hand, at the West Virginia station Jonathan seedlings were found to be successful for the varieties used (Sudds and Marth, 1943). Studies at several other eastern state agricultural experiment stations indicate that seedlings of the following varieties make good nursery stocks: Delicious, Rome Beauty, Winesap, Whitney, Ben Davis, McIntosh, Windsor, Northern Spy, Allen Choice, Oldenburg, Gano, and Tolman. According to the same reports, seedlings of the following varieties make inferior stocks: Gravenstein, Baldwin, Grimes, Stark, Stayman Winesap, Rhode Island Greening, Wealthy, and Tompkins King.

Experiments with seedlings at certain stations indicate that varieties differ in suitability as rootstocks for any one variety of apple. For example, seedlings of McIntosh made large trees of York Imperial, but produced dwarfs of the variety Staymared (Sudds and Marth, 1943). From results with nine-year-old

trees of four varieties on seedlings of ten varieties, Sudds and Marth deduced that it would be hazardous to predict the general performance of the seedlings of any one variety by the responses obtained with a limited number of varieties worked upon them. And later Sudds (1944) concluded from the results of other experiments: "Apparently causes other than seedling rootstocks account for most of the variation in growth and production in our deciduous orchards."

In the trade, seedlings from commercial apple varieties still retain, as perhaps they should, the name of French. According to one wholesale nursery firm in Portland, Oregon, a small portion of the seed was still imported from France until the outbreak of World War II; and some customers insisted that their orders be filled with seedlings produced from this seed.

Judging from recent work by McClintock (1938), Yerkes and Anthony (1941), and Schrader and Haut (1941), there may be other apple stocks which, for some varieties, would be superior to the stocks thus far tried in California. There is long experience, however, behind the seedlings now in use; and any change, except for special purposes, should be adopted only after many years of trial. Were they available, there would be a place for roots resistant to certain insect pests and diseases, for dwarfing stocks for home gardens, and for adaptation to certain adverse soil conditions.

There are no available records of comparative tests, as rootstocks, of the various crab varieties and species in California. Both culinary and ornamental crab-apple varieties and species grow well on French seedlings (Wyman, 1943); there is only one reported exception—the Bechtel crab, which is short-lived on common apple seedlings. The Siberian crab, *Malus baccata* Linn, is hardy in cold regions and does well in limy soils. This stock might be useful in high Sierra valleys and in Modoc County. Undoubtedly, however, the very old apple trees around farm houses in that area are on French roots. A large specimen of Yellow crab, said to be the Yellow Siberian, was observed at a farmstead east of the Warner Mountains in Modoc County. In 1940, budwood from this tree was placed in a seedling at Davis, and the resulting tree is now bearing fruits in quantity.

The Virginia crab is reported by McClintock (1938) and others to impart increased vegetative growth to certain cultivated varieties of apple, but to dwarf others, and to be highly resistant to at least one of the collar rot fungi, *Phythopthora cactorum*. Apparently a form of the common apple which has escaped domestication, the Virginia crab has been propagated only by vegetative means, since its seedlings are not of uniform character. A few experimental trees of these have been planted in Mendocino County by the California Agricultural Experiment Station. Being also cold resistant, the Virginia crab as a rootstock might be of use in high Sierra valleys and eastward. It is more or less dwarfing to the varieties Winesap, Stayman Winesap, and Mammoth Black Twig.

Trees on French apple roots do best on a deep loam soil, although profitable orchards have been observed on both sandy and heavy soils. Heavy soils, however, must be well drained, naturally or artificially. The trees tolerate wet feet less well than, for instance, do pear varieties on French pear roots. In Sonoma County, pear trees are found in orchards in low wet spots where apple trees have failed to prosper. Trees on soils underlain by layers impervious to water

and too level for drainage are sometimes injured by excess soil water. Shallow soils underlain with gravel or sand do not provide conditions suitable to the best development of the apple-tree root system. Judging from observations in areas of marly soil, the apple is less subject to lime-induced chlorosis than are pear varieties on common French pear and quince roots, although it is not entirely free from this trouble. On deep loams, the roots penetrate deeply and spread widely.

Apple varieties on French apple roots used as replants where trees have died in very old orchards often fail to grow rapidly. This trouble is conspicuous when the scion variety is a slow grower, such as Yellow Newtown and Jonathan. To hasten the development of a large root system for replants, several growers in the Watsonville district have planted the vigorous Black Twig and Winter Banana varieties on common French roots and top-worked them after a few years—the Black Twig to Yellow Newtown and the Banana to Delicious. Judging from observation of these plantings, the system has some merit. Several plantings at Watsonville are greatly hindered in root development because the growers have followed an old tradition—that to make a large root system, the young trees must be headed back severely every winter for many years. As a highly successful grower in that district pointed out, vigorous intermediate stocks cannot take the place of good culture, fertilization, and light pruning in establishing replants in old orchards. In planting, he digs very large holes and fills them with top soil.

In Sonoma County, one orchard was observed in which Winter Banana was used, apparently with success, as the intermediary stock on which Jonathan was grafted after a large root system had been established. Another grower used Rhode Island Greening and King, to which he later grafted the slow-growing Jonathan, Rome Beauty, and Wagner.

We have no records regarding the depth and lateral spread of apple roots in the various soil types in California. Records from other places might, however, be of interest to growers here. In Nebraska, in an unirrigated loess (porous silt loam) soil, apple trees seventeen years old were found to have penetrated to a depth of 35 feet (to a shale), and to have used 85 per cent of the available moisture down to 30 feet (Wiggans, 1935). Yocum (1937), reporting on unirrigated three-year-old apple trees in Nebraska, found that in a clay loam soil the roots had penetrated to a depth of 12.7 feet and, in a more porous silt loam, 17 feet. They had, however, spread laterally farther in the clay loam—13 feet from the trunk—than in the silt loam. In the silt loam, the trees had absorbed about half of the total available moisture to a depth of 9 feet, directly beneath the trees. Yocum also found that intercrops of corn caused the lateral roots to grow downward as they approached the drier soil near the corn. In Oregon, it was found that only soils with 10 per cent, or more, of pore space, in addition to that occupied by water at field capacity, are satisfactory for the growth of apple trees (Stevenson, 1935). In England, Rogers and Vyvyan (1934) observed that in a sandy soil the roots spread farther horizontally but penetrated less deeply than in a clay soil. In clay, the roots were much shorter and more twisting and branching than in sand. Most California apple orchards are in unirrigated sections, where the summers are practically rainless and the average annual precipitation is 20 to 40 inches. Even where

the rainfall is as much as the latter amount, irrigation is, as a rule, beneficial.

In California, apple on pear or quince roots seldom makes a vigorous tree. From other regions, however, come reports of partially successful apple orchards on these roots. For instance, at the New Mexico Agricultural Experiment Station, experiments were started in 1910 to test the use of pear roots for Stark Delicious and King David apples, to avoid injury from the woolly aphid, *Eriosoma lanigera* (New Mexico Agricultural Experiment Station, 1910–11). These varieties were budded to the scaffold branches of young pear trees, but some of the pear branches were left unbudded. The variety of pear used is not stated. The union appeared to be strong, the trees made good growth, and most of them bore fruit each year; but, on the whole, they were unsatisfactory, as reported in 1924, when the experiment was terminated (New Mexico Agricultural Experiment Station, 1923–24). Usually, the apple branches increased in diameter faster than the pear; and at fourteen years of age, some were reported to be distinctly top-heavy. The fruits were smaller than those borne on trees on apple roots. For home gardens, in situations too wet for apple roots, pear and quince trees could be top-worked to apple—perhaps with some degree of success. Also, where the oak-root-fungus disease, *Armillaria mellea,* is present, they could be tried on French pear roots.

In the orchard at Davis, Yellow Newtown and Gravenstein grafts grew vigorously and normally the first year on young trees of the blight-resistant Old Home pear. In the second year, however, they slowed down in vigor; and in the third year, they appeared distinctly unhealthy. At the Davis station, apple was successfully grown on its own root by bench grafting long scions upon short piece roots of French pear, and planting in the nursery with the graft union several inches below ground. Six of these planted in the orchard had grown to normal stature when removed at six years of age, and had large apple roots above the pear.

The successful use of quince as a stock for apple is described in a communication from Uruguay (Argles, 1937), where quince seedlings were satisfactory for the Winter Banana variety and for a local variety known as Colorado Temprana; the seedlings made small, early-bearing trees which found a large-scale commercial use. Some of these trees lived to be more than twenty years of age. Argles does not specify the variety or type of quince used. In 1944, a preliminary trial of this graft combination was begun at the Davis station. Winter Banana and Yellow Newtown were budded in the nursery to Angers quince (East Malling Selection A). In the first year, the three Banana scions grew to an average height of 55 inches, with a stem diameter of ¾ inch. The three Newtown scions reached a height of only 25 inches and an average diameter of ¼ inch. The unions were all strongly knit. In February, 1946, the trees were transplanted to the orchard. In October, 1946, the three Banana trees were growing vigorously, whereas the only Newtown tree that survived transplanting was not doing well.

Mr. E. Sartori, Pomologist at the University of Buenos Aires, in a statement to the author in 1944, said that a local apple—Cara Sucia—grows well on quince root in Argentina. Of some sixty apple varieties tried, only this one is successful. It is of poor quality, and is useful only for jelly, jam, and cider when mixed with more flavorsome varieties. It grows rather dwarfishly, how-

ever, on quince—an apple-shaped strain common in that country. Recently, Cara Sucia has been tried as an intermediate stock between quince and the better varieties, and at five years of age this graft combination appears promising for wet soils and for the elimination of woolly aphid on the root system. Mr. Sartori also stated that apples are used on quince in Uruguay.

Possibly quince could be adapted in California as a stock in some wet situations and in some home gardens, although, at present, there is no definite information regarding the apple varieties and types of quince which might be used under such conditions.

Vegetative Propagation of Apple Roots

The Davis station, a number of years ago, secured from the East Malling Experiment Station in England a series of vegetatively produced apple stocks with which that station had been working for more than twenty years. Most of these form roots readily by layering and by use of root cuttings. These represent a series of selections ranging from dwarfing (Paradise) and semidwarfing (Doucin) to the free-growing or vigorous stocks. The dwarfing and semidwarfing forms might be useful for temporary interplants among standard trees or for home yards; they could also be used for espalier or trellis training. The most pronounced dwarfing form—Malling No. IX (also known as Jaune de Metz)—has a very weak root system with many thickened fiber roots. These latter often spring approximately from one spot, and form a knot that resembles somewhat the hairy root form of crown gall, *Phytomonas rhizogenes* R.B.W.K.S. In fact, one California nurseryman reports that he could not sell or deliver dwarf trees on Paradise stock, because horticultural inspectors mistook these knots for the hairy root form of crown gall. Paradise stock, in reality, is fairly susceptible to crown gall. Further, none of the East Malling stocks are resistant to the woolly aphid. Unless the stocks prove to be more suitable than ordinary seedlings to certain soils or to other conditions, none of them, except possibly the dwarfing ones, are likely to find a place in California horticulture. In the nursery, some of the apple varieties have not made smooth unions with certain of these stocks. The vigorous-growing varieties have overgrown the dwarfing stocks, although the unions seem to be strong.

The root system of No. IX so often lacks large roots that the trees require staking against strong winds. In layering, No. IX does not produce many sprouts. It propagates readily, however, by short root cuttings, which have yielded 70 to 95 per cent stand under conditions at the Davis station. Dwarfing has also been secured in tests at experiment stations in the East by a double-working process in which No. IX was grafted to French seedlings, and apple varieties, in turn, were grafted upon the No. IX intermediate piece. Thus, Tukey and Brase (1943), at the New York Agricultural Experiment Station, secured a partial dwarfing effect by using No. IX as an intermediate stock, for stem piece, between French seedling roots and several apple varieties—Baldwin, Delicious, Early McIntosh, and McIntosh. The most complete dwarfing was attained, however, only when No. IX roots were employed.

Roots of the Northern Spy variety have been used, to a limited extent, in the eastern states and very commonly in some other countries as a stock resistant to the woolly aphid. In California, however, it has been used but sparingly.

A few trees on this root were planted in orchards in Sonoma and Mendocino counties many years ago; but, except for a few trees in Mendocino County, their locations are unknown. A few trees on the woolly-aphid-resistant Delicious roots have been observed. Since the seedlings produced from seeds of the Northern Spy and Delicious varieties are not usually resistant to this pest, they must be grown on their own roots by root cuttings, or by layering, or by piece-root grafts. This characteristic naturally makes them much more expensive; and Pacific Coast nurserymen are not inclined to produce them by such tedious and uncertain processes. One nurseryman in Mendocino County grew them some years ago; but, since the growers were unaccustomed to the flat-spreading and irregularly shaped root systems of the nursery trees produced by this method, he could not make many sales. Since Northern Spy is reported to form a poor union with some varieties, an intermediate stock is necessary, in such cases, to avoid making dwarfish trees. According to Hearman (1936), a review of literature in the field indicates that Northern Spy is satisfactory in some parts of the world but not in others. When it fails to give satisfaction, the cause is usually stated to be a poorly developed, shallow root system which involves poor anchorage and a great susceptibility to drought conditions.

Tests at Davis gave no success in rooting Northern Spy from stem, and only a small percentage by root cuttings. The variety rooted readily, however, by trench layering and by piece-root grafts. In one trial at Davis, a 90 per cent stand of piece-root grafts was secured by grafting a 6-inch scion of Northern Spy on a 2-inch piece of Northern Spy root. The July after planting, these were large enough to be budded to the desired variety. Of course, scions of the desired varieties can be grafted to a piece of any suitable root; but, when such a combination was planted, the graft union would be far below the surface, and roots would grow from the scion above the union.

At the Davis station, Delicious was produced by root cuttings and by piece-root grafts on Delicious stems, with practically the same degree of success accomplished with Northern Spy, related above. It rooted readily by both mound and trench layering.

Diseases, Insects, and Rodents in Relation to Apple Roots

Apple roots are susceptible to the crown gall disease, *Phytomonas tumefaciens,* although once the trees are well established in the orchard, the disease seldom attacks them seriously. Grafted stocks often form hard galls over the lower end of the graft tongue; and an inspector is likely to condemn nursery trees of this sort on suspicion that they are affected by the true bacterial crown gall, for the disease often affects them at this point. The hairy root form of crown gall is seldom met with in California-grown nursery stock. Nurserymen of California report that crown gall in the nursery is seldom so serious on apple stocks as it is on the stone fruits.

French apple roots are partially resistant to the oak root fungus. Considerable loss from the disease occurs in certain apple districts. Instead of attacking the root directly, this rot more commonly infects and kills the scion variety if the bud union is planted below the ground or if it becomes covered in cultural operations—the disease then running both upward and downward into the

root system. Because of this manner of attack, and the partial resistance of French apple roots, many of the affected trees can be saved by surgery if the disease is discovered before too much damage has been done. Surgery has been standard with a number of growers in Sonoma County for some years. Of course, the original source of the disease may remain deeply hidden in the soil to recur later.

A new root rot of fruit trees and ornamentals, caused by the fungus *Dematophora* (*Rosellinia*) *necatrix,* has been observed in several counties of California (Thomas, Hansen, and Thomas, 1934). The disease appears to be most serious on apple, and spreads more rapidly in the orchard than does the oak root fungus. Its symptoms closely resemble those of the latter disease—for which it has undoubtedly sometimes been mistaken. Both fungi produce a whitish growth in the bark at and beneath the surface of the ground. Oak root fungus is distinguishable by white fan-shaped mats of fungus in the bark or between the bark and wood, and by black or brown shoestring-like strands on the surface of roots. In wet soil, dematophora produces a loose cottony growth on the surface of roots and in openings in the soil close to the tree trunk; this growth turns black with age. There is evidence that the disease is spread by cultivating tools as infected pieces of root are dragged from affected areas and dropped near other trees. Spots should be isolated and either left uncultivated or worked separately.

Apples are susceptible to fire blight—pear blight, *Bacillus amylovorus*—which can quickly girdle and kill trees on French apple root. In California, however, this phase of fire blight with apples has been less serious than with pears.

At the California station, Day and Tufts (1944) have tested the seedlings of Rainier and Delicious for resistance to root-knot nematodes, *Heterodera maroni.* These two varieties were not attacked by the pest. One nurseryman in the San Joaquin Valley reports having seen slight infestations on French apple seedlings. From other states, apple seedlings are reported to be affected but not sufficiently injured to prevent successful growth of orchards in infested soil.

The meadow nematode, *Anguillulina pratensis,* which does not form knots, has been reported by Ark and Thomas (1936) in apple and other fruit-tree roots in Sonoma County in certain soils. There, it is apparently doing some damage, although some of the unhealthy condition may have been caused by other factors.

The woolly apple aphid is among the more serious insect pests of the apple, both on the roots and on parts aboveground. Rootstocks resistant to this pest would be very helpful, because there would be no aphids below ground to reinfest the tops after spraying operations—a condition which now occurs. Thus far, however, a completely satisfactory rootstock has not been fully demonstrated.

A slight infestation of woolly aphid on the rooted layers of Northern Spy occurred at the Davis station, but it was not sufficient to cause root injury. The layered trees were on seedling apple roots heavily infested with this pest. In experiments with Delicious on its own roots, at Davis, there was but slight infestation. The infested roots were on layered trees, which in turn were on

seedling roots; and the latter were severely affected by this pest. On the other hand, at Berkeley, W. H. Chandler reported heavy infestation on Delicious roots and tops of young trees alongside Northern Spy trees which were free from the pest.

Apple roots are about as subject to attack by pocket gophers as are myrobalan plum and peach roots, and much more so than are pear roots.

Summary of Rootstocks Used for Apple Varieties

The foregoing discussion of rootstocks for apple varieties in California has pointed out that the seedlings from France, on which the old orchards were planted, were a mixture derived from seeds of small-fruited forms, which had run wild, and of larger dessert and cooking varieties, from the cider presses of France and Austria. Despite their diverse origin, these seedlings made satisfactory trees of considerable uniformity of vigor and fruitfulness. The so-called French seedlings grown from seeds of certain common commercial varieties, chiefly in Oregon and Washington, are the only ones now available; but these are apparently as satisfactory as those formerly obtained in Europe. A good, well-tested rootstock resistant to the woolly apple aphid is highly desirable, but no completely satisfactory one has yet been fully demonstrated. For dwarf trees for home gardens the East Malling Paradise apple selection No. IX (page 10), which is propagated by root cuttings, is available only in limited quantities at the present time. The use of the Malling No. IX as an intermediate stock between French seedling roots and apple variety tops has also resulted in dwarf trees in experiments elsewhere, but has not been tried in California.

Rootstocks are discussed in relation to insect pests, diseases, and tolerance to various soil conditions. Observations and experiments with various other roots and intermediate stocks are recorded.

ROOTSTOCKS USED FOR QUINCE VARIETIES

Quince varieties are grown only on roots of their own species, *Cydonia oblonga,* and in California are now produced almost entirely on their own roots by stem cuttings and by budding onto rooted stem cuttings. In the earlier days, the nurserymen imported from France rooted cuttings of the Angers quince (named after the city of Angers) and to these they budded the cultivated varieties. At present, a few seedlings are secured from Oregon for use in nursery budding.

In California the cultivated varieties propagate more or less readily by hardwood stem cuttings planted directly in the nursery row. At the Davis station the varieties Rea, Orange, Apple, West Mammoth, Burbank, and de Antequera (S.P.I. No. 33214) were found to propagate readily, whereas Pineapple, Smyrna, Van Deman, Sweet Winter, and Wayne County Orange did not give a very good stand in the nursery row. In France, heel cuttings are used for certain varieties that do not root well by straight stem cuttings (Buse, 1943). Cuttings planted at Davis in late November or early December rooted better than those planted later in the winter.

Seeds of the varieties mentioned above have been grown in the experimental nursery at Davis. They seemed to make no better nursery stock than

Fig. 1.—Hardy pear fourteen years old on quince roots. Note the graft union and the horizontal, branching quince root system upon which the excavated tree can stand almost vertically without props. Compare with figures 11, 12, and 13.

Fig. 2.—Bur-knots on trunk and branches of quince.

did stem cuttings. Of the varieties tested, Smyrna produced the most promising seedlings.

The greatest use of rooted quince cuttings in California is for rootstocks for pear trees; for this purpose, nurserymen prefer the Angers type, which roots freely and is a strong grower. The Portugal quince, although likewise a strong grower, was reported by early nurserymen to root poorly by cuttings. The use of quince roots for pear varieties is discussed in detail under the section devoted to rootstocks for pear trees (pages 32 and 36).

Some quince varieties are reported to grow successfully when top-worked upon apple, although the author has not observed this combination in California. In the nursery at Davis, Angers quince made fair growth, but formed weak unions when budded upon apple and pear seedlings. No observations have been made of quince varieties top-worked upon pear trees. Angers quince on pear seedlings planted in the orchard were dwarfish and chlorotic when removed at the end of their second year.

California nurserymen who have grown the Oriental flowering quinces, *Cydonia* sp., state that these grow well when grafted upon common quince, but that they also succeed by root and stem cuttings and, except for the weaker varieties, are usually propagated by this method. Loquat and Low photinia, *Photinia serrulata,* are reported to grow well upon quince roots.

Because the quince root can tolerate rather wet soil conditions, it is often used, in California, as a stock for pear in low wet spots in pear orchards that are otherwise on French pear roots. The roots do not penetrate so deeply in overwet soils, however, as in soils kept properly moist, nor do the trees do well in these swampy areas.

The quince does better on a moderately heavy than on a lighter soil. Apparently its habit is to send up many feeding roots near the surface. In western New York, where the quince is an important commercial crop, it is reported that the growers, in order to establish the main roots at a greater depth, plant the trees rather deep and, for the first few years, work the soil away from them.

The root system of the quince with a pear top does not penetrate so deeply as does the French pear root, but spreads out horizontally in an extensive network of small roots (fig. 1). On deep loam soil of the Yolo series at Davis, in a twelve-year-old orchard that was pulled by tractor, the main roots spread out horizontally for about 2 feet from the trunk, then curved downward, and soon subdivided freely without penetrating deeply. Pear roots in adjacent rows took an angle of about 45 degrees downward and ran straight in that direction for 6 to 8 feet.

Diseases, Insects, and Rodents in Relation to Quince Roots

The quince root seems not particularly subject to infection by the crown gall disease. The trunks and branches are often covered with large rough knots, which, until lately, were supposed to be crown gall or some similar parasitic tumorous disease. These have been definitely proved, however, to be burknots (fig. 2); they consist of large groups of root primordia, which grow through the inner bark, stop near the surface, and then remain dormant. The presence of such root primordia, either singly or in conspicuous groups, is

thought to be the reason why quince is so readily propagated by stem cuttings. A check of mature trees showed that, with the exception of Orange, those varieties which had the most bur-knots were the ones which grew most readily from cuttings.

Although quince is susceptible to attack by fire blight, *Phytomonas amylovora,* the trees of most quince varieties do not succumb so readily as do the trees of certain pears, including Bartlett. When used as a rootstock for pear orchards, quince is prone to send up suckers, and these shoots sometimes conduct blight down to the root system.

Quince is susceptible to chlorosis from excess lime in the soil, and pear trees become more chlorotic in highly calcareous soils on this root than on French pear root.

The quince is highly susceptible to the oak-root-fungus disease. It is reported to be susceptible to, but seldom injured by, the root-knot nematode. Rooted cuttings of the following varieties were grown by Day and Tufts (1944) for two years in a nematode-test nursery at Delhi, California, without developing a single knot: Rea, Orange, Burbank, Angers (Gregory type), de Antequera (S.P.I. 33214), and the East Malling stocks A (Angers), C, and D. It is practically immune to the pear root aphid, *Eriosoma lanuginosum* (Hartig).

No observations have been made concerning injury to quince roots by rodents. Since, however, the trees are often seen growing in fence rows and in neglected situations, apparently quince is not much favored by pocket gophers and mice.

ROOTSTOCKS USED FOR PEAR VARIETIES

Early commercial pear orchards of California were on so-called French (*Pyrus communis*) pear seedling roots, either imported from Europe or propagated from seed secured from seedling pear trees growing in the Mission gardens and in other pioneer orchards. During the gold rush, Chinese miners brought in and planted seeds of the Chinese pears, *Pyrus pyrifolia* (*P. serotina*), later known as the Japanese pear, along the streams of the Sierra Nevada. So far as is known, seed from these Japanese pears was not used by early nurserymen for seedlings on which to propagate commercial varieties.

Until about 1918, most of the pear plantings were on seedling roots grown from seed imported from France, whence the name French. Seed of the Japanese-French hybrid variety Kieffer was used somewhat, and still other orchards were propagated on quince roots.

Between 1912 and 1925 the pear acreage expanded greatly. Early in this era, some of the new orchards were planted on *Pyrus pyrifolia* roots, and from 1918 to 1926 practically all were on this root. In this latter period, there were a few plantings on seedlings of other Oriental pear species (*P. ussuriensis, P. calleryana,* and *P. betulaefolia*). Of the few plantings on *P. calleryana* made up to about 1932, most were budded in the nursery to the blight-resistant Old Home pear and top-worked in the orchard to Bartlett. The trial of these new stocks was largely due to investigations at the Southern Oregon Agricultural Experiment Station, where Reimer (1925) made an extensive search for pear roots and bodies resistant to fire blight. The merits of pear varieties on Old Home and other blight-resistant trunks and scaffold branches

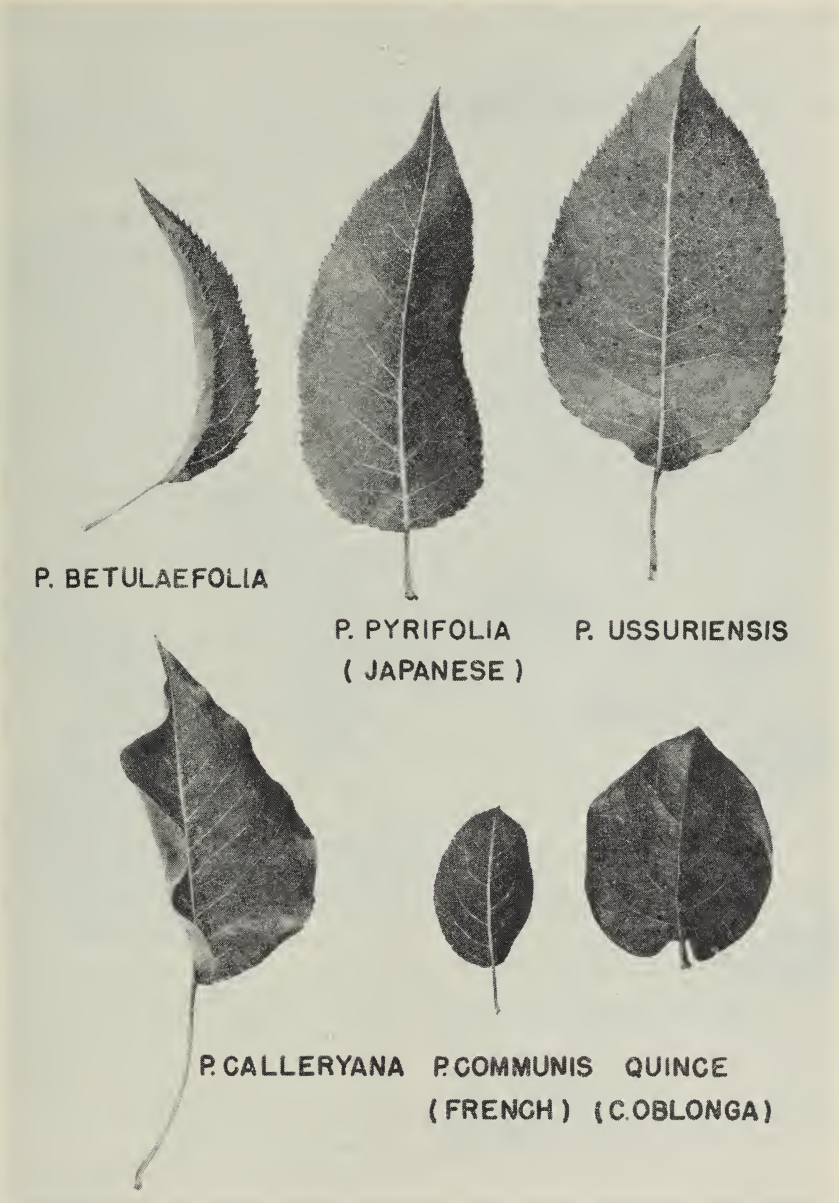


Fig. 3.—Leaves of six rootstock species used for pear orchards in California. These show the comparative size and other characteristics of average leaves. Approximately ½ natural size.

to prevent blight from running downward through the trunks to the roots are discussed in detail in later sections.

Pear is known to grow well on several species of *Pyrus* besides the ones mentioned above, and more or less successfully upon certain other closely

allied pomaceous species, such as quince, apple, hawthorn, mountain ash, cotoneaster, service berry, medlar, and toyon, or Christmas berry. None of these are in common use except quince, which is discussed in detail in later pages. On quince and on the species which are still less congenial, the pear tends to form roots of its own above the graft union, where this point is several inches below ground.

Fig. 4.—Twig of seedling of French pear (*Pyrus communis*). Twigs are brown or purplish brown; tips sometimes pubescent; often thorny. Leaves are roundish to oblong, with either rounded or acute apex; they either are toothless or have small teeth without bristles. This species suckers freely.

At the Davis station there is a collection consisting of twenty-eight pear species—including several subspecies and hybrids. Most of these were furnished by the Southern Oregon branch station in 1922. Bartlett has been planted at Davis on seedlings of eleven of these species (besides the blight-resistant ones mentioned above, which are discussed in considerable detail in later sections). Their growth to date, after six years' trial in the orchard, is summarized as follows: 1) satisfactory —*Pyrus phaeocarpa, P. cordata, P. glabrata, P. parviflora, P. bretschneideri,* and *P. serrulata;* 2) semidwarfish—*P. persica, P. ovoidea,* and *P. cotinifolia;* and 3) dwarfish—*P. heterophylla* and *P. balansae.*

Trees of Bartlett on apple roots have been observed in California. In general, they were not very satisfactory. Several, however, that had been grafted at the ground some forty years earlier, upon some unidentified apple variety, were normal in size and production. A few fifteen-year-old replants in an alkali spot were below normal in size, but apparently as satisfactory as adjacent ones on common pear root. All were removed, however, because of the inhospitable soil condition. In the nursery at Davis, Bartlett on common apple seedlings grew vigorously, although examination of the unions revealed some physical defects in the bark and wood. Also at Davis several Red Astrachan apple trees grafted over to Bartlett were growing fairly well when removed at five years of age. The unions, however, showed some defects in both the bark and wood. According to reports from several outside sources, pear varieties on apple are usually neither vigorous nor long-lived.

Occasionally one needs to know whether a pear tree is on apple or pear root. This is readily determined by chewing and tasting a small piece of bark

of the root in question and comparing it, for flavor, with the bark of apple and pear stems. Apple bark—root or stem—has a sweetish taste, with little of the astringency or the puckery flavor of the pear. Pear roots are brownish—often Ridgway's walnut brown—whereas apple is much lighter, some shade of buff to ochraceous tawny (Ridgway, 1912).

Fig. 5.—Twig of seedling of Japanese pear (*Pyrus pyrifolia*). Young twigs glossy green with large lenticels and usually without thorns. Leaves large with long-tapering points; sometimes pubescent at first, but usually smooth when fully grown. Teeth are coarse and sometimes tipped with short bristles.

In Alameda County a Bartlett pear orchard thirty years old was observed to be partly on hawthorn and partly on French pear roots. The trees on hawthorn were somewhat smaller and less vigorous than those on pear.

In Mexico the pear is often grown on a native hawthorn (*Crataegus mexicana* Moc. & Sesse), locally called tejocote, and varieties on this root are believed by the growers to endure drought better than when on other roots. A. D. Shamel, Principal Pomologist, United States Department Agriculture, Bureau of Plant Industry, at Riverside, California, in a letter dated August 1, 1939, to the author, said that in Mexico he saw tejocote grafted over to pear, which "united perfectly with the tejocote limbs and were growing strongly."

Identification of the Pear and Quince Species Used in California as Rootstock for Pears

Pear rootstock species cannot be identified in the orchard unless suckers arise from below the graft union. Figure 3 illustrates the relative size of the leaves, and figures 4 to 9 show terminal portions of the twigs of the stocks mentioned above. Since, in any one species, the leaves and other characters vary considerably from seedling to seedling, photographs can represent only selected average individuals. The pear varieties often form roots above the union; and these may give rise to suckers, which make it difficult to determine the original rootstock species.

Fig. 6.—Twig of seedling of *Pyrus ussuriensis* pear. Twigs of young shoots are smooth, not pubescent, greenish yellow, and sometimes rather thorny. Apex of leaves usually abruptly pointed. Bristles on marginal teeth usually much longer than on *P. pyrifolia*, from which it sometimes cannot be distinguished except by fruits.

Pyrus communis (French) Seedlings. The tendency to sucker and the small size of the leaves usually identify the French seedling stocks (fig. 3). All other species used as pear stocks in California have larger leaves. The leaves of the French are roundish to oblong, with either rounded or acute apex and rounded base. The margins may be either toothless or small-toothed without bristles. The plants are usually thorny; the twigs (fig. 4) are usually brown or purplish brown; and, at first, the terminal parts are often covered with a gray pubescence, although this varies from seedling to seedling.

Pyrus pyrifolia (Japanese) Seedlings. The leaves (figs. 3 and 5) are usually two or three times as long and broad as those of the French, with long tapering points and coarse-toothed margins. This species does not sucker readily. At first the leaves are somewhat pubescent, but when full grown they are usually smooth. The young shoots have a glossy green bark, with many and large lenticels, and are usually free from spines. It is not always easy to distinguish by leaves and twigs between *P. pyrifolia* and *P. ussuriensis*. On old trunks, however, the bark of *P. pyrifolia* is deeply furrowed but less freely cross-checked than in *P. ussuriensis*. The fruits of *P. pyrifolia* (fig. 8) have long stems, are roundish, small to medium in size, and brownish russet; the calyx is usually deciduous.

Pyrus ussuriensis Seedlings. The apex of the leaves of this species is usually abruptly pointed (figs. 3 and 6) rather than tapering to a point, common with *P. pyrifolia*. This character, however, as well as that of the marginal teeth, varies so much in both species that the two are often difficult to separate. The leaves of *P. ussuriensis* are usually free from pubescence, even when young, and the bristles on the marginal teeth are usually much longer than those of the other species. The fruits (fig. 8) are small to medium in size, roundish, and greenish yellow; the calyx is large and not deciduous, as in *P. pyrifolia*, and the stems are short and thick. The twigs of typical young seedlings are smooth, free from pubescence, and greenish yellow. Some of the seedlings are very thorny; others almost thornless.

Pyrus calleryana Seedlings. The green, glossy leaves of this species (figs. 3 and 7) are medium-sized to large, ovate, with wavy margins. The scalloped or rounded teeth are small, without bristles. On young wood, the bark is smooth and glossy, and the new shoots may or may not be pubescent. The fruits (fig. 8), about 1/3 inch in diameter, round, and entirely covered with russet, are borne in clusters; the calyx is deciduous.

Fig. 7.—Twig of seedling of *Pyrus calleryana* pear. Note the ovate leaves with wavy or crinkly margins which have only small teeth without bristles. The shoots may or may not be covered with a gray pubescence.

Pyrus betulaefolia Seedlings. This species is readily distinguished from the other stocks by the dense, light-gray pubescence which covers the young shoots and leaves. The leaves (figs. 3 and 9) are smaller and narrower than those of the other Oriental species. They are wedge-shaped at the base, with long tapering apex and with margins coarsely toothed. Pubescence gives a light grayish-green color to the leaves. The fruit (fig. 8) is about 1/4 inch in diameter and is borne in clusters. Since the trees grow straggly, with horizontal or drooping branches, they can hardly be used to set in the orchard for later top-working to commercial varieties. The seedlings have few, or no, thorns.

Quince (Cydonia oblonga) Seedlings and Cuttings. Quince shoots are readily distinguished from any of the pear rootstocks by the leaves (figs. 3 and 10), which are roundish to oval in outline, the margins smooth and wavy, the apex acute, the base either rounded or slightly heart-shaped. In size, the leaves are intermediate between those of the French and the other pear rootstock species, and are pubescent on the under side. The twigs are slender and spineless, and at first the terminal parts are usually covered with a fine gray pubescence.

Pyrus Communis as a Rootstock for Pears

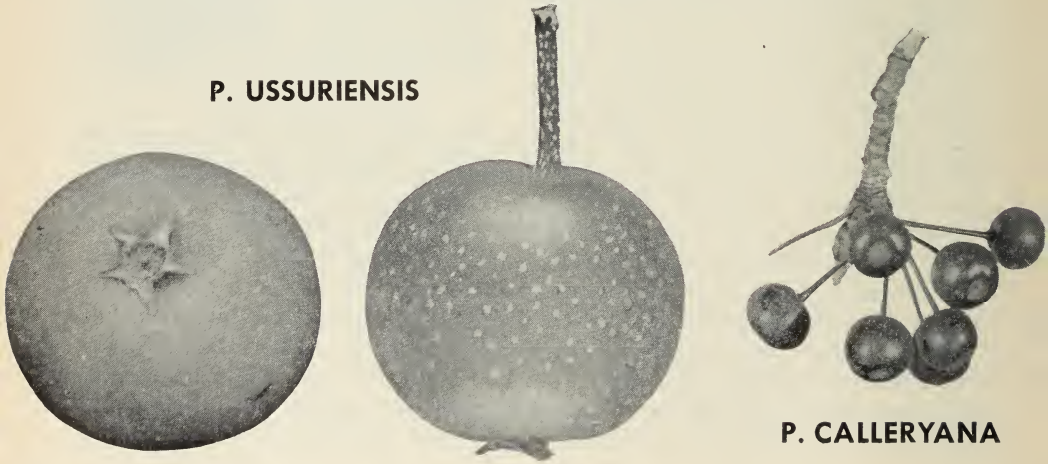
The cultivated pear is commonly referred to the species *Pyrus communis*. Geneticists agree, however, that two or more pear species are involved in its origin. Judging from the uniformity of old orchards in California, seedlings of this species imported from France made good understocks. Even for some years before World War I, however, pear seeds and seedlings were not imported in any quantity from Europe. Instead, California nurserymen have been securing their French pear seedlings from Oregon and Washington nurseries. These are generally grown from seeds of Bartlett and Winter Nelis. These so-called French pear seedlings form the roots upon which the California nurseryman grafts or buds commercial varieties.

The seeds of many pear varieties have been planted for comparison in the nursery at Davis. Of the common varieties, Winter Nelis made the most vigorous and satisfactory nursery stock, with Hardy and Bartlett next in order. Whether pears on Winter Nelis will eventually make more vigorous orchard trees than those on Bartlett and Hardy seedlings is controversial. In Lake County, several fine old Bartlett pear orchards are said to be on Winter Nelis seedlings.

The French, or common, pear seedling is a vigorous stock, unites well with all pear varieties, and makes a robust root system. The root crown often grows larger than the trunk of the scion. Such a condition is not unhealthy; some of the best Bartlett trees in an orchard are often of this type. Exaggerated cases are known as churn-bottomed trees (fig. 11, p. 26).

This root grows in a variety of soils. It tolerates relatively wet, heavy soils; but trees growing in orchards with a high water table grow less thriftily and produce less heavily than trees whose roots can penetrate deeper. Although the trees endure shallow soils remarkably well, on deep, fertile soil, they will, of course, be more vigorous and produce more profitable crops. Many successful orchards are located on deep sandy loams along the rivers.

Fig. 8.—Fruits of *Pyrus ussuriensis, P. calleryana, P. betulaefolia,* and *P. pyrifolia* (Japanese pear). *P. ussuriensis* after Reimer. Approximately normal size.



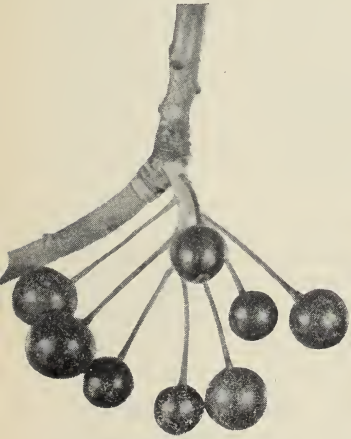
This pear species tolerates a greater range of soil-moisture conditions than others tested. Its root system penetrates deeply, is wide spreading, and is as well anchored as, or better than, any of the deciduous fruit trees, with the possible exception of black walnut and almond. Since the roots are tough, the under-cutter in the nursery pulls harder than with the roots of stone fruits.

The roots will not grow into waterlogged soil. Examination of trees pulled by tractor in a swampy ravine in an old orchard in Placer County disclosed a very restricted root system. The main roots were very short, subdividing at about 3 feet from the trunk into smaller and smaller roots; and practically the whole root system adhered in a dense mat 5 to 6 feet in diameter and only 12 to 18 inches deep. Pear varieties on French pear root cannot endure excess lime in the soil, although they are far less affected by lime-induced chlorosis than are those on Japanese and *Pyrus calleryana* pear, or on quince roots. They tolerate some alkali, although less than those on *P. betulaefolia* seedlings.

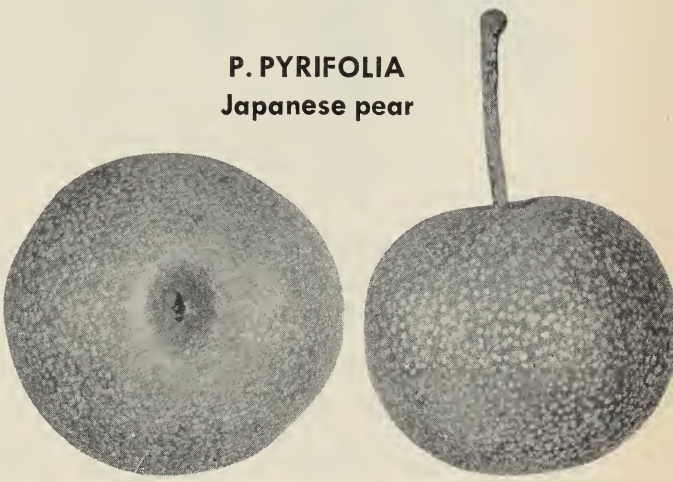
Excess boron dwarfs pear trees or reduces the yield of fruit, but does not produce characteristic leaf or twig symptoms. It is not known, however, whether the Bartlett or other varieties behave differently in this regard when on different rootstocks.

Trees on French pear roots are resistant to the oak root fungus and seldom die of the disease. Sometimes they are used to replant areas in stone-fruit orchards, where the trees have been killed by this rot. They are, however, susceptible to the somewhat similar dematophora root rot (Thomas, Hansen, and Thomas, 1934) (see p. 12).

The two serious faults of the French pear seedling root are its susceptibility to the pear root aphid and to fire blight (pear blight). Some individual French seedlings seem to be more susceptible to aphid than others; an affected orchard on this root may have both stunted and normal trees. In unirrigated orchards, especially, this difference seems to be evident in drought years—the heavily infested trees do most poorly. Injury by this pest is largely a matter of killing of the small rootlets. There are no swellings nor galls on the roots, such as those caused by the somewhat similar woolly aphid of apple roots.



P. BETULAEFOLIA



P. PYRIFOLIA
Japanese pear

The tendency of French roots to send up suckers greatly increases the danger of blight infections on underground parts. Seedlings of the blight-resistant French variety Old Home are not resistant unless the seeds from which they were grown have been hybridized in the blossom stage by pollen from another blight-resistant variety.

Fig. 9.—Twig of seedling of *Pyrus betulaefolia* pear. Young shoots and leaves are covered by a dense light-gray pubescence. The leaves are curved and have a long tapering apex and coarse-toothed margins.

At the Davis station, the author tested the blight-resistant qualities of several hundred seedlings, grown from seeds of Old Home, whose flowers had been pollinated by near-by Farmingdale trees—the Old Home being sterile to its own pollen. There were no other pear varieties within 5 miles of the orchard in which these trees were growing. Inoculation of these seedlings with the fire-blight bacteria indicated that many were nearly immune, and that all seemed to be much more resistant than seedlings of Winter Nelis and Hardy tested at the same time in adjacent nursery rows. Reimer (1925), working at the

Southern Oregon station, had previously reported that seedlings of Old Home × Farmingdale were resistant.

For blight-resistant framework branches, Old Home has been most commonly used because of its wide-angled crotches; and there are many commercial orchards of this variety grafted on seedlings of blight-resistant species (fig. 17, p. 40) and on the nonresistant French pear roots. The use of French roots obviously is a weak link, because blight enter into the root system through suckers, plow scars, and insect punctures.

In the nursery, French pear roots are less susceptible to crown gall than are some of the stone fruits; in the orchard, trees are seldom seriously affected.

The root-knot nematode does not seriously impair the growth of trees on French roots. In a nematode-resistant experimental nursery (Day and Tufts, 1944), seedlings of thirteen varieties were tested for two years. Those from seed of P. Barry, Easter, Hardy, and Winter Nelis showed light infestation only: Angouleme (Duchess d'Angouleme), Howell, Comice, Bosc, Bartlett, Seckel, and Anjou were moderately affected; and Variolosa seedlings were resistant the one year they were tested.

Pocket gophers may cause serious injury to French pear roots. This rodent is especially troublesome in unirrigated orchards and in the mountains where furrow irrigation does not completely wet the entire surface. Field mice sometimes girdle the trees at the ground level when grass and weeds are not cleared away. In wet situations, the trunk and root crown of young pear trees on this root may become affected by crown-rot fungi (*Phytophthora* sp.).

Fig. 10.—Twig of quince, *Cydonia oblonga*. The twigs are slender and spineless; at first the terminal parts are usually covered with a fine gray pubescence. The leaves are roundish to oval in outline; the margins smooth and wavy; the base either rounded or slightly heart-shaped; the underside pubescent.

Pyrus Pyrifolia as a Rootstock for Pears

Seedlings of the so-called Japanese pear, *Pyrus pyrifolia,* have been used as a rootstock for cultivated pear varieties in America for nearly half a century. Old, successful orchards on this root exist in the southern and eastern parts

of the United States and in Oregon and Washington. In 1912, California growers began to use this species. Between 1918 and 1926, when California's pear industry had its greatest expansion, this rootstock was employed almost exclusively. Supposedly, it had several advantages over the French root. Unlike the latter, it seldom sends up suckers to become exposed to fire blight. Nurserymen liked it particularly well, because it grew more thriftily than the French stock and was practically free from the pear root aphid. In fact, the Japanese root received so much praise that for years the growers would buy nothing else. At one time, according to estimates, 40 to 50 per cent of the pear orchards in California were on this root. In 1918, George P. Weldon, Chief Deputy State Commissioner of Horticulture, cautioned growers regarding the use of this and other new rootstock species: "We must not, however, be too hasty in our conclusions and, before definite recommendations are made for this state, there should be careful experimental work done with these promising varieties and species under our conditions. Mr. A. L. Wisker of Grass Valley has been one of the pioneers in the work of experimentation with Japanese roots and results have been fairly satisfactory, so much so in fact that he, as a practical nurseryman, has given up the use of the French root for propagating purposes, with the result that other nurserymen in the state have followed his example."

Fig. 11.—Bartlett pear on French roots. An exaggerated case of "churn-bottom," as it is commonly called. Note also the inarched sucker on the right-hand side. The top of a sucker was grafted into the bark above to bridge a wound made by surgical operations on a fire-blight canker.

Disappointingly, however, this root proved not much more resistant to blight than did the French. Where a blight canker extended down the trunk, the root crown was girdled almost as readily as the French root. This species has proved to be less resistant to oak root fungus than French stocks, and does not tolerate wet soils nor drought nor shallow soil so well as the latter. In other soils, however, it produced strong, healthy trees—partially, perhaps, because of its resistance to pear root aphid. Many cases of crown rot were observed in the wet spring of 1928 in Mendocino, Placer, and El Dorado counties, on Bartlett trees on this root. Presumably the crown rot was due to the same phytophthora fungi that caused similar cankers on stone fruit trees that year in near-by orchards.

About 1920, there began to appear in many young Bartlett pear orchards a fruit condition known to growers, shippers, and canners as black-end, or

hard-end. The chief manifestation of this trouble is a hardening and rounding out of the blossom end, or the development of black spots in that region, or a combination of both on the same fruit. Investigations have shown that this trouble is almost entirely confined to orchards growing on this and certain other Oriental roots; for this reason, after 1926 very few trees were planted on *Pyrus pyrifolia* root. Because of this disease, fire blight, and economic conditions in the industry, about 30 per cent of the pear acreage in California has been taken out during the past ten or twelve years. Since these were largely younger orchards, total production has not been correspondingly reduced.

Black-end has also been found to occur, although in a lesser degree, on pear trees on *Pyrus ussuriensis* and *P. betulaefolia* roots. It has also been observed on Bartlett pears propagated on roots of seedlings of the Kieffer pear. Only a few cases of the trouble have been observed on Bartlett worked upon seedlings of French or upon *P. calleryana*. The individual trees worked on the former of these two stocks, however, may have been on roots of stray seedlings of Japanese or of hybrids of this species, such as Kieffer. The use of Old Home pear as a blight-resistant trunk between the Bartlett top and Japanese roots appears not to influence the occurrence of black-end in the Bartlett fruits. The only pear variety grown commercially in California which is practically free from black-end, or hard-end, on Japanese roots is Hardy.

In areas with marly subsoils, trees on *Pyrus pyrifolia* are more subject to lime-induced chlorosis than are those on French roots, but less than those on quince. *P. pyrifolia* does not sucker from below the graft union so freely as do French roots. It makes a smooth, uniform union with the Bartlett, and the crown does not grow larger than the Bartlett trunk.

According to Tufts and Hansen (1931), in certain sections and in some seasons, longer Bartlett fruits may be secured from trees on French than on Japanese roots. Evidence shows no difference in the blooming dates of Bartlett trees on these two stocks. Allen has found that fruit from Japanese-rooted trees growing where soil moisture is limited are firmer, are higher in soluble solids, and ripen with higher color than fruit from trees on French stock.

Veihmeyer and Hendrickson (1938) report that Japanese pear roots seem not to spread through the soil uniformly, even in a homogeneous soil.

Pyrus Ussuriensis as a Rootstock for Pears

Pyrus ussuriensis, another Oriental stock, has been tried in a number of orchards as a seedling and later top-worked to the desired variety. Although it resists pear root aphid and produces a blight-resistant trunk—the seedlings themselves being resistant—many varieties on this root develop black-end disease; but the proportion of the trees affected is smaller than on Japanese root.

Individual specimens of *Pyrus ussuriensis* differ in vigor and in congeniality with the Bartlett. In some trees the growth rate of stock and scion is about equal, and the union is almost inconspicuous. In some cases, the Bartlett may overgrow the *P. ussuriensis* seedling, but in others it may fail to grow even as rapidly as *P. ussuriensis*. In one of the oldest orchards on this root, the Bartlett trees are distinctly larger than adjacent Bartletts on *P. pyrifolia* roots (with Old Home as an intermediate stock). Old Home works well on *P. ussuriensis* seedling roots as an intermediate stock for Bartlett.

In one sixteen-year-old Bartlett orchard in Placer County, on both French and *Pyrus ussuriensis* roots, many of the trees on the latter are larger than those on French roots. The *P. ussuriensis* seedlings are grown directly in the orchard and top-worked to the Bartlett. In small trees, apparently the Bartlett has always grown faster than the *ussuriensis* understock. The varieties Bosc, Comice, Bartlett, and Anjou have grown well on *ussuriensis* roots in this orchard. Some of the Bartlett trees yielded black-end fruits, which the owner pulled out over a series of years and replanted with Old Home on its own roots, and later top-worked to Bartlett.

When *Pyrus ussuriensis* is used for top-working, its identity may be detected by the leaves on suckers and the scaly condition of the bark immediately below the graft union. The scaly condition begins much earlier in life than with other common stocks. The bark is less deeply furrowed than in the Japanese trunks and is more freely cross-checked.

This root is not attacked by the pear root aphid. It is not resistant to oak root fungus, although in two large orchards where myrobalan-rooted plum trees have been seriously invaded by this disease, there has been practically no damage to roots of *Pyrus ussuriensis, calleryana,* and *pyrifolia.* In one orchard near Placerville, pocket gophers were observed to have girdled many of the trees on *ussuriensis* roots.

Reimer (1925) in Oregon, found that seedlings of the wild trees from China were less vigorous than those from cultivated Chinese varieties of this species.

Pyrus Calleryana as a Rootstock for Pears

Seedlings of another blight-resistant Oriental species, *Pyrus calleryana,* have been used with varying degrees of success as a stock, especially for the Old Home when used as an intermediate trunk and scaffolding (fig. 17, p. 40). Several Bartlett orchards with the latter combination have been bearing for twelve to fifteen years and promise to be entirely satisfactory.

In but one of these orchards has black-end been observed, although only a few trees were noted and the affected fruits on each was negligible. Possibly, therefore, the trees showing this condition are on some other rootstock. The seeds of *Pyrus betulaefolia* so closely resemble those of *P. calleryana* that collectors in China might not always distinguish between them. The trees also might be hybrids of these two or with other species. Since, however, black-end has been serious on the two Oriental species previously discussed, this station has been reluctant to advise the use of *calleryana* roots.

At Davis in 1927 there were planted, in alternate rows, five trees each of Old Home on *Pyrus calleryana,* French, and *betulaefolia* seedling roots (figs. 12, 13, and 14). The Old Home on French has grown more slowly than on either of the other two. All were top-worked to Bartlett in 1934. In 1940, when this experimental orchard was pulled out, the average trunk circumference, in inches, was as follows: *calleryana* 30.4, French 20.0, *betulaefolia* 29.0. The presence of root aphid on the French roots may partially account for the relatively slower growth of the trees on that root.

In 1924, in one large pear orchard in Yolo County, Old Home was planted on *Pyrus calleryana,* French, and *ussuriensis* roots. The trees were top-worked to Bartlett and Winter Nelis when two or three years of age. When measured

recently, they were all about the same size. In a twenty-year-old orchard in Yuba County, there are alternate rows of Bartlett trees on French and *calleryana* roots (both with Old Home as an intermediate stock); there seems to be no difference in growth and fruitfulness.

Fig. 12.—Old Home tree, fourteen years old, on *Pyrus calleryana* roots. Note the long, slender roots with but little branching.

One California nurseryman who raised *Pyrus calleryana* seedlings for a few years reports that because of the large proportion of small, poorly rooted trees, the production of pear varieties on this root was an unprofitable nursery venture. Reimer (1925) reports that both *P. calleryana* and *P. betulaefolia* tend to make poorly branched root systems. If, however, the taproots are cut back when one year old and then replanted in the nursery, a well-branched root system can be developed. Reimer further notes that the varieties Old Home, Bartlett, Anjou, Bosc, Comice, Howell, and Winter Nelis have grown exceptionally well on *calleryana*. On the other hand, Tukey and Brase (1943) found this root unsatisfactory in New York State for Bartlett, Anjou, Seckel, and Kieffer.

Some pear varieties overgrow the *Pyrus calleryana* root, but this condition does not seriously interfere with the success of the tree. Trees on this root bear younger and more heavily than those on French roots. When, however, the Old Home is used as an intermediate stock, the Bartlett performs normally. In the experimental nursery at Davis, *calleryana* seedlings made good growth.

Fig. 13.—Old Home tree, fourteen years old, on French pear roots. Root system usually more branching than that of the Oriental species.

Bartlett budded directly to them did not grow vigorously, although Old Home was very thrifty.

The roots of *Pyrus calleryana* seedlings are resistant to the pear root aphid, but are less resistant to oak root fungus than French. Bartlett trees on this root in lands with limy subsoils were observed to become highly chlorotic.

Reimer (1925) has seen this species growing wild in the Orient in soils varying from granite and coarse sands to very heavy clay: "It was often observed growing on very dry mountain sides, on various valley lands, along streams and in wet, poorly drained swamps."

In recent years, *Pyrus calleryana* has become the favorite rootstock in the southeastern part of the United States; it makes rapid-growing rootstocks in the nursery and unites well with most varieties (Drain, 1940). In California it would perhaps be useful only as a blight-resistant rootstock for blight-resistant bodies, such as Old Home.

To secure uniform vigorous rootstocks of this species, nurserymen may

select and grow parent seed trees. Some success in growing nursery trees by root cuttings has been had at the Davis station. A vigorous seedling was selected for this purpose. One year, a stand of 85 per cent of root cuttings was secured, although in other seasons a much smaller percentage grew. This selection had a widespread root system. After taking up the two-year-old trees from

Fig. 14.—Old Home, fourteen years old, on *Pyrus betulaefolia* roots. Note that roots do not branch so freely as do French pear roots.

the nursery, and cutting off an average of ten root cuttings per tree for propagation purposes, there still remained a good root system for transplanting to the orchard.

Pyrus Betulaefolia as a Rootstock for Pears

Another Oriental species that may thrive in certain soils is *Pyrus betulaefolia*. Although not uniformly resistant to blight, this root is less easily infected than are those of French pear seedlings. Reimer (1925) notes that some of these seedlings were very resistant to blight and "may become very valuable as the parents of rootstocks, since this species propagates more readily from root cuttings than any other." He found that Old Home grew faster on this stock than on French, and that six commercial varieties slightly surpassed in vigor the same varieties on French roots. These results correspond with the planting at Davis referred to on page 28, and shown in figures 12, 13, and 14.

Since some pear varieties are not congenial with *Pyrus betulaefolia,* the Old Home should be used as an intermediate stock (fig. 14). In New York State, Anjou is not congenial, whereas Bartlett, Kieffer, and Seckel do well upon it (Tukey and Brase, 1943). In a letter to the author, in 1938, Reimer reports that in Oregon, Anjou and Bartlett make perfect unions; Winter Nelis, Bosc, Howell, and Comice tend to overgrow this stock; and some Anjou trees on *P. betulaefolia* have developed a limited amount of black-end.

As to the soil adaptations of *Pyrus betulaefolia,* Reimer states: "The writer found this species growing in a great variety of soils in the Orient, varying from coarse sand to heavy clays; and from high, dry, droughty hillsides to low, flat, swampy places. . . . In the Honan Province, it is often used as a wind and sand break in the sand and alkali regions where very few other shrubs and trees thrive. . . . Judging from observations in the Orient and also from the behavior of trees growing on sandy and gravelly spots at this station [Talent, Oregon] it is likely that this species will endure drought better than any other *Pyrus.* This is probably due to the habit the roots possess of growing down to a great depth in such soils." On alkali or marl soils, where other roots cannot be used, *P. betulaefolia* may possibly prove satisfactory.

Some twenty years ago, Reimer furnished trees for a comparative test plot of pear rootstock species in an alkali soil in Stanislaus County. In this plot, *Pyrus betulaefolia* seedlings performed better than French, *pyrifolia,* or *ussuriensis* seedlings. In this same orchard, in an area less alkaline, were comparative rows of Bartlett on *betulaefolia, calleryana,* Japanese, and French roots. A few of each, except those on French, have borne black-end pears.

One-year-old seedlings of *Pyrus calleryana* and *P. betulaefolia* were more sensitive when transplanted to alkali soil than were older ones. *P. betulaefolia* roots are fairly resistant to attack by pear root aphid. No observations concerning its resistance to the oak-root fungus have been made. Since three other Oriental species are susceptible to this disease, however, it must be regarded with suspicion.

Quince as a Rootstock for Pears

In California a number of pear orchards have been planted on quince roots, generally with Hardy as an intermediate stock. Bartlett, as well as some other varieties, does not make a satisfactory union with any of the quince roots used in California. Bartlett trees worked directly on quince are usually dwarfish, tend to break at the union, and are not long-lived. With Hardy as an intermediate stock, the trees are long-lived, although smaller than when on French pear roots. By close planting, however, one can secure a yield per acre as great as with the latter root; and some growers prefer this combination because of earlier bearing, together with economy in harvesting, pruning, spraying, and blight surgery. The usual planting distance for these dwarf trees is about 18 by 18 feet, although some are as close as 16 by 16 feet. Some of the orchards are now over thirty-five years old and still in good production.

One thirty-five-year-old planting in Contra Costa County is on Angers quince with Bartlett budded to the Hardy trunk, about 1 foot above the ground (Swett, 1917). The trees were still bearing well in 1944. They attained their present height of 11 feet when twelve years of age. Since this orchard

is unirrigated, heavy sets must be thinned so that the fruits will grow to full size. Thinning must also be practiced whenever the rainfall is deficient.

Bartlett fruits from these double-worked trees are often of larger sizes, of better color, and of the long type desired by certain canners and shippers. These superior characteristics may not persist, however, as the trees grow older. Trees that are allowed to overbear tend, after a few years, to produce smaller fruits. For continued success and long life, trees apparently need careful pruning and other cultural attention. Being especially liable to sunburn during the first summer after planting, their trunks must be protected soon after they are transplanted to the orchard. The large wound, where the Hardy was cut back to the Bartlett bud, is a vulnerable spot for flat-headed borers the first year, both in the nursery and in the orchard.

The quince root is used more commonly in the Santa Clara Valley than elsewhere. The practice there, in the orchard, is to plant Hardy on quince root and when the tree is three to five years old, to graft the desired variety out about 10 inches on the scaffold branches. These growers believe that trees double-worked in the scaffolds do much better than those double-worked in the nursery—or even in the trunks of orchard-grown trees—and that the 2- or 3-inch Hardy interpiece in nursery double-worked trees results in too much dwarfing. Perhaps, however, the better growth from double-working in the orchard is largely a result of greater impetus given to the roots by the Hardy top during the years before top-working, for the Hardy worked directly on quince grows almost as vigorously as on French roots. At Davis, Bartletts with the short Hardy interpiece were doing well when pulled out at an age of ten or twelve years. Double-working in the scaffolds offers a better chance to rework the tree in later years if a change of variety becomes desirable.

In the Santa Clara Valley the following varieties have been observed to be performing well when double-worked in the scaffold branches of Hardy (on quince roots): Bartlett, Bosc, Winter Nelis, Anjou, and Comice. Easter on Hardy bears well for five or six years, then rapidly loses in vigor of growth—perhaps because of overbearing.

With all varieties observed here, a heavy set necessitates much care in proper sizing of the fruit. The trees need good pruning, thinning of fruit, and irrigation. With the shallow quince root system, several light irrigations do more good than a single heavy one. It is particularly desirable to irrigate once just before the fruits begin to ripen and, if necessary, again after the first picking.

Nurserymen often have difficulty in producing the double-worked tree in the nursery row. In order to produce a tree in the two years in which a nursery is usually retained on a plot of ground, one must resort to various expedients. Bench grafting the Hardy to whole roots of quince before lining out in the nursery, and also June budding either the Hardy or the Bartlett, in order to gain a year, are methods practiced. Bench grafting must be done high on the trunk so that, when planted in the orchard, the Hardy union will not be more than an inch or two below ground; otherwise the Hardy will grow roots above the union, and thus defeat the dwarfing purposes for which the quince root was intended.

The following varieties are reported to produce satisfactory dwarf trees when worked directly on quince roots: Glou Morceau, Anjou, Angouleme,

Howell, Seckel, White Doyenne, Vermont Beauty, Clapp Favorite, and Kieffer. For orchard purposes, however, it seems better to double-work all of these in the scaffold branches of Hardy. Comice, worked directly on quince roots, grows rapidly until it gets into heavy production; then it declines in vigor and the fruits cannot be forced to good size. As with the pear varieties double-worked with Hardy, it requires good cultural operations to size the fruit to marketable grades. The following varieties seldom do well if worked directly on quince: Bartlett, Bosc, Nelis, Seckel, Easter, Clairgeau, Comice, and Guyot (Dr. Jules Guyot, often listed as Early Bartlett).

Experiments at the Davis station with certain blight-resistant French varieties indicate that Old Home should make a very satisfactory substitute for Hardy as an intermediate stock for quince roots, and could be top-worked high to Bartlett and to other varieties to give a blight-resistant framework. Also, as discussed later (p. 36), when planted deeply, Old Home sends out strong roots above the graft union, and a blight-resistant root system can be secured thereby.

Reports from Australia indicate that where Kieffer pear is grown on wet soils, better setting of fruit occurs on quince than on French pear roots. Also, whereas Easter and Vicar of Winkefield were distinct failures, Glou Morceau and Diel performed well on quince.

The dwarfing propensities of quince root for pear varieties is sometimes utilized to produce small trees for home gardens and to train pear trees on trellises and against walls. According to Argles (1937), this root has been used for centuries in Europe to encourage precocious fruiting and to adapt the pear tree to garden culture.

Pear trees on quince root should be planted with the bud union slightly below the soil surface, to prevent suckering, for quince suckers are susceptible to fire blight and will conduct the disease to parts underground. If planted more than 3 or 4 inches deep, the pear throws out roots of its own above the bud union, and the tree finally attains standard size.

In Placer County, in a low area too wet for pear roots, there is a test plot of Old Home on quince roots. After nine years, trees are growing normally, except in spots that remained swampy throughout the year. Here, the quince has developed a large mass of short roots near the surface, and the trees are poorly anchored against the wind. In the wet spring of 1940 most of them developed cankers in the Old Home trunks aboveground and died. The nature of the cankers was not determined, although presumably the trouble was caused by crown-rot fungi.

In California, several strains of quince propagated by cuttings are used by the nurserymen as stocks for pears. One of the desirable strains is supposed to be the French Angers. Nurserymen favor this type because it roots readily by cuttings, grows large enough the first season to be budded in the late summer, and performs satisfactorily in the orchard. Angers quince has long been reported to have some resistance to fire blight in California.

The East Malling Station in England has selected types of quince commonly used in that country and in Europe. These, given the literal designations of A to G, have been on trial at Davis for some years. Quince A is of the Angers stock and is considered the best of that type in use there. Quince B is the only

other one that seems worthy of consideration as a pear rootstock from a commercial viewpoint. It dwarfs the trees more than does the Angers type. Quince E is of the Portugal type. It does not propagate readily, nor has it proved to be so invigorating a rootstock as old accounts of its performance would lead one to expect.

One cannot always state positively that certain pear varieties do well or poorly when worked directly on quince. The results may depend upon the strain of quince. Experience indicates, however, that Hardy unites with the quince strains used in California; and Old Home has united well with all the strains used at Davis. According to Hatton (1936), the experiments at the

Table 1

AVERAGE SIZE OF THREE-YEAR-OLD TREES OF OLD HOME AND HARDY PEARS ON ROOTS OF TEN VARIETIES OF QUINCE

Quince varieties used as rootstocks (stem cuttings)	Number of Old Home trees	Old Home diameter	Number of Hardy trees	Hardy diameter
		inches		inches
Angers A.	9	2.16	6	1.49
Wayne County Orange	10	1.96	9	1.65
De Antequera (S.P.I. No. 33214)	4	1.88	..	....
Unknown variety	8	1.85	..	....
Smyrna (two-year-old trees)	4	1.29	..	....
Rea	11	1.73	23	1.41
Burbank	6	1.69	19	1.53
Bourgeat	9	1.29	5	1.69
Pineapple	10	1.26	10	1.57
Apple	11	1.22	9	1.41

East Malling Station with selected quince stocks indicate that these vary in compatibility with any one pear variety, and also that the seven pear varieties tested vary in compatibility with any one quince stock, so that the study of quince stocks in relation to pear varieties may be complex.

Table 1 gives the diameter of three-year-old trees of Old Home and Hardy pears on roots—from stem cuttings—of ten varieties of quince, which were grown in an orchard near Winters, Yolo County. The trees did not display equal vigor on the various quince roots. Old Home made larger trees than Hardy in four cases and smaller in three.

Among the advantages of quince stock for pear are resistance to pear root aphid and tolerance to excess soil moisture. Quince trees are not resistant to the oak root fungus. The black-end trouble, rather common on most pear varieties on certain Oriental pear rootstocks, has not been observed on quince roots. Quince is not tolerant of excess lime; and in soils with marly subsoils, pear varieties on quince become more chlorotic than do those on French pear roots. Quince is partially (although not entirely) resistant to nematodes; it seems to grow in spite of these pests.

Sometimes one must determine whether a pear tree in an orchard is on quince or pear roots. A ready index is color, the quince being black to blackish brown, whereas common pear root is a lighter brown, usually walnut brown.

Pear on Old Home and Other Blight-Resistant Roots

Blight-resistant pear species on whose roots Old Home is used as a blight-resistant trunk have been briefly discussed in previous sections (pages 30 and 31). The greater acreage of pear orchards on Old Home trunks is, however, on the nonresistant French seedling roots. Obviously this is a weak link in the prevention of damage by blight, for the French root is not only nonresistant, but has a tendency to send up suckers which readily conduct the disease downward into the roots. As mentioned earlier, the Old Home is a blight-resistant French seedling selection, but seedlings grown from its seeds are not resistant. It would, therefore, be highly desirable to produce this variety on its own roots by some method of vegetative propagation—for example, by root cuttings, by layering, or by growing the Old Home on some other root with the graft union placed below ground. Considerable experimental work along these lines has been done at Davis. Old Home does not root by stem cuttings, nor very readily by cuttings from roots of Old Home trees produced originally on their own roots by layering. Although the variety produces roots readily by trench layering, this method was found rather impractical for producing trees in the extensive way required in California horticulture.

From 25 to 50 per cent of the sprouts from trench-layered Old Home trees made satisfactory roots at Davis. Best results by the layering method were secured by covering the layered trees in the nursery with 2 inches of fine peat moss; when the shoots came through the moss, fine soil was placed around them.

Several unsuccessful trials were made at Davis to reproduce Old Home by root cuttings of own-rooted trees. Fair success was had with root cuttings from certain seedlings produced from Old Home seeds that were pollinated with pollen of the blight-resistant Farmingdale pear, and also with root cuttings from seedlings of Winter Nelis, Easter, Seckel, *Pyrus calleryana,* and *P. betulaefolia.* Long scions of Old Home were grafted upon short piece roots of quince; and when these were planted, with the union several inches below the soil surface, roots of Old Home grew out above the union and made successful trees after the quince had been cut off and the rooted Old Home scions replanted in the nursery. Old Home scions on piece roots of Old Home were not very successful. Old Home on its own roots, whether produced by root cuttings from layers, or by piece-root grafts, must have a strongly developed root system before being transplanted to the orchard; otherwise it will not grow thriftily. Two years in the nursery are usually required to develop such a root system.

As related previously, grafted Old Home trees tend to root if the graft or bud union is planted below ground. This has been observed when it is on roots of French, *Pyrus calleryana, P. ussuriensis,* and quince. The scion roots usually do not form before the third year.

A few trees, twelve to fifteen years old, of Old Home on their own roots have been observed; these appear to grow as well as Old Home grafted on roots of French pear and other seedling stocks. Bartlett, top-worked upon these self-rooted trees, appears to be growing normally.

Possibly the most practical way to put Old Home on its own roots is to use

nursery trees consisting of Old Home on quince roots, planted in the orchard with the graft union about 12 inches below the soil surface. Experimental test of this method was begun by the author at the Davis station in 1933 (Day, 1937). Figure 15 shows one of these trees, pulled up by tractor at the age of six years, on which the Old Home root system had developed above the graft

Fig. 15.—Six-year-old self-rooted Old Home pear tree. Produced by planting Old Home on quince roots with the bud union 12 inches below the soil surface.

union. The quince root had by this time begun to assume a minor role as compared with the Old Home roots. The Old Home trees grew more rapidly on quince than did those near by on French roots. To test the behavior and scion rooting of Old Home on quince under various soil conditions, about one hundred and fifty of these trees have been planted in privately owned orchards in Santa Clara, Lake, Placer, Nevada, and Mendocino counties. Some of them were top-worked to Bartlett at four years of age. The oldest of these top-worked trees are now nine years of age; they are of normal size and productivity. One grower in the Santa Clara Valley has recently planted a considerable acreage with trees of Old Home on quince purchased from a commercial nursery.

The roots of pear trees on Old Home on quince, planted sufficiently deep, should be safer from blight infection than if planted at the usual depth either on quince or French root. No quince suckers have yet appeared aboveground around trees now nine years old. Inasmuch as quince with Hardy as a trunk and scaffolding has long been satisfactorily used, and Old Home likewise has had a quarter of a century of use as an intermediate stock for French roots, there would be little likelihood of any serious difficulty arising from the practice described above.

In 1937 two trees, each of Old Home, were planted on quince with unions 12, 18, and 24 inches below ground level. These have grown well; and the ones planted with union 24 inches deep have, from the beginning, grown a little faster than those planted 12 and 18 inches deep. Such deep planting probably would not be successful in a very heavy soil. There seems, however, to be no advantage in placing the unions more than 10 or 12 inches below the soil surface. Unlike Old Home root, quince is resistant to the pear root aphid. In many situations, therefore, the use of quince should enable young Old Home trees to get a normal start, whereas on French seedling roots they would be retarded in early life.

Since Old Home is a French variety, it is perhaps resistant to oak root fungus. A few trees up to fifteen years of age have been observed growing in plum orchards where this disease is present. The Old Home is susceptible to a bark canker (blast) which either stunts growth or kills the tree outright (Smith, 1941). This canker is caused by a bacterial organism, *Bacterium syringae,* similar to, or perhaps identical with, that which causes one form of bacterial canker (bacterial gummosis) of stone fruits and blossom blast of the pear. This bark canker has been under observation for some ten or twelve years. It attacks not only Old Home but Wilder Early, Lawson (Comet), Anjou, Nelis, Bartlett, Easter, Surprise, Variolosa, and Bosc trees. Although the cankers are somewhat similar to those of fire blight, blight operators can usually detect the difference. This disease does not run far below ground. Thus far it appears to be of minor importance to pear orchards on Old Home trunks.

Cankers similar to crown rot of stone fruits and apparently caused by the same organisms also occasionally affect the Old Home near the soil surface and kill the bark for some distance both above ground and below. This trouble has also been noted with both French and Japanese pear roots.

Pear on Old Home Trunks and Scaffolds. The experience of growers of Bartlett and other varieties on Old Home trunks and scaffolds which, in turn, are on French and other roots, should furnish some valuable suggestions for the use of Old Home on its own roots secured through the use of quince as a starter, described above. The following discussion might therefore be of value to growers interested in this system.

Successful orchards of Bartlett, Hardy, Bosc, Nelis, Comice, and Wilder, top-worked upon Old Home scaffolds, have been observed for fifteen to twenty-five years. One observation is that a resistant root and body do not confer any resistant qualities to the varieties top-worked upon them nor, perhaps, even materially reduce the number of infections occurring in the blossoms. The chief value of Old Home trunk and scaffold branches is in preventing blight

from running downward from the susceptible-variety top to the roots. Also, its scaffold branches have wide-angled crotches, which assist materially in producing a wide-spreading top-worked tree. Observations have been made for some twenty-five years in several of the largest California orchards, including one of 480 acres which is mostly on resistant roots and scaffolds. These studies show that the resistant understocks have literally saved the orchards in years of general blight epidemics, but that they have not helped much to prevent or reduce the number of infections in the blossoms and twigs. Clearly, in these orchards the blossom infections originate almost exclusively from small, ob-

Fig. 16.—Leaves and fruit of the Old Home pear.

scure overwintering cankers in the upper parts of the trees—infections that cannot be found in the fall and winter through the most careful inspection by experienced operators. In these orchards, such cankers have been much more potent in scattering blight that the overwintering cankers lower down on the main scaffolds.

The Old Home itself does not produce fruits of good quality; hence, it is important only as an understock resistant to blight.

In top-worked trees, the Old Home branches often grow in diameter faster than the Bartlett top. The scaffold branch, therefore, is often greater in diameter below the graft union than above it. This condition has not, however, proved detrimental.

Often Old Home suckers between the rows reveal that roots have grown out above the graft unions of deeply planted trees. The following description will assist in identifying suckers from self-rooted Old Home trees or shoots and fruits on the trunks of top-worked trees of this variety.

The leaves (fig. 16) of the Old Home pear resemble those of the Bartlett. Marginal teeth are either small or almost lacking. At first the upper surface

Fig. 17.—Bartlett top-worked upon framework of the blight-resistant Old Home pear, which is in turn on French roots. Ten branches were budded (at positions shown by arrows), to Bartlett when the Old Home was three years old in the orchard. Had the Old Home tree not made sufficient growth to provide proper spread and height, the budding operation would have been postponed to the fourth year.

is pubescent, giving the leaves a grayish color; but this soon weathers away, leaving the surface green and glossy. Young twigs are also slightly pubescent, although this condition soon disappears, leaving a pinkish color, particularly on the sunny side. The fruits (fig. 16) are medium large, round, greenish, ripening to pale yellow, with the stem set in a very shallow cavity; the calyx is open and in a shallow basin; the fruits are gritty and of poor quality.

Experiments and observations in commercial orchards indicate that in the top-working of Bartlett to Old Home, the best results have been attained by budding or grafting the trees at three or four years of age, in secondary or tertiary branches at shoulder height and not less than 10 or 12 inches out from the junction with the main branch. This practice gives a wide-spreading tree with ten to twelve Bartlett branches (fig. 17). When blight attacks the Bartlett top, the disease stops at the graft union. A new Bartlett graft may then be put into the Old Home stub, or else a bud placed into new shoots that arise from it. When blight kills a Bartlett branch top-grafted too close to the ground, a new graft is more difficult to train up, because of shading by higher branches. In several orchards, in seasons when blight was not very active, the cankers in Bartlett branches usually stopped in their downward course before reaching the graft union, and new Bartlett sprouts then grew above the union. Where zinc chloride solutions were used to arrest and prevent deep penetration of pear blight (fire blight) cankers, Old Home bark was penetrated by this material more readily than Bartlett; for this reason, one should not let the solution run very far below the union.

Davis and Tufts (1941) report that Old Home successfully pollinates Bartlett flowers. The Old Home blooms at the same time as the Bartlett; and if the orchardist having this combination will permit a few flowering hangers to develop from the Old Home framework, his pollination problem will be taken care of satisfactorily. Since the fruits are unlike those of the Bartlett, there will be no confusion during harvest. In Michigan, Johnston (1936) found Old Home a satisfactory pollinator for Bartlett, Bosc, Seckel, Clapp Favorite, Howell, Kieffer, and Flemish Beauty.

Other Blight-Resistant Trunks and Scaffolds. In several test orchard plots established in 1931 for study of the behavior, pruning, and top-working of blight-resistant varieties, the following were included for comparison: Old Home, Lemon, Variolosa, Surprise, and Farmingdale—all on French roots. With the possible exception of Variolosa, all belong to the same species as the California commercial pears. According to Reimer (1925) Variolosa appears to be a hybrid between *Pyrus pashia* and common pear. Of the varieties named above, Old Home, Lemon, and Variolosa are the most vigorous and appear to be the most promising. Lemon makes a well-shaped, spreading framework suitable for top-working to Bartlett or other varieties. If it proves resistant to blast, it might make a satisfactory understock and a possible substitute for Old Home. Variolosa tends to grow so upright that it requires considerable pruning skill to avoid the development of sharp-angled crotches. Surprise, on the other hand, often does not form enough lateral branches for good top-working. Fine Bartlett trees have been established, however, on all the above stocks; and at sixteen years of age they are performing normally in size of crops and fruit.

Lemon, Variolosa, Farmingdale, and Surprise root less readily by layering than Old Home. Both Lemon and Variolosa on their own roots (produced by layering) have grown well in the orchard. Two of the Lemon trees are now fourteen years old; the Variolosa, six. In another test, Lemon and Farmingdale planted on quince roots with unions 12 inches below the ground level, have rooted above the union and, at four years of age, had established blight-resistant root systems. At six years, however, only Lemon is growing with normal vigor, and Farmingdale is distinctly dwarfish. Variolosa did not produce scion roots. The union between Lemon and quince, being rather weak, is readily broken at this point in nursery operations. At four years of age the quince root not only had failed to flourish but had died and rotted off at the union. Besides the above cases, two other blight-resistant varieties (now six years old) made good growth when planted deeply on quince roots—namely, Burkett and Old Home No. 50. They have grown good pear scion roots above the union. Old Home No. 50 is a vigorous seedling of Old Home selected by Reimer at the Oregon station. On the other hand, the following blight-resistant varieties (planted deeply on quince roots) in the same planting are below normal in size: Variolosa, Lincoln, Estella, Tyson, Snyder, Longworth, Douglas, and Surprise. A vigorous selection of *Pyrus ussuriensis* and one of two selections of *P. calleryana* failed to grow well on quince. One vigorous selection of the latter grew well, however, and has formed roots above the union. The thirteen varieties discussed above are under test for resistance to the bacterial bark canker (blast) as possible substitutes for Old Home, should the disease prove too serious on that variety.

Summary of Rootstocks Used for Pears

Pears are grown in California on the so-called French pear roots, with or without the blight-resistant Old Home as an intermediate stock; and on quince roots with Hardy as intermediate. The French roots now used are mostly seedlings from Bartlett seeds. Roots of several Oriental species have also been used for resistance to blight and root aphid, but at least three of these have produced black-end fruits, with considerable financial loss to the growers.

According to experimental orchard tests, apparently Old Home could be substituted for Hardy as the intermediate stock between quince roots and pear variety tops. When planted with the graft union 10 or 12 inches below ground it would produce Old Home roots above the quince, and thus furnish resistance below ground as well as in the trunk and scaffold branches.

The relation of the various rootstock species to insect pests and diseases and tolerance to soil conditions are discussed. Observations and experiments with various other roots and intermediate stocks are recorded.

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